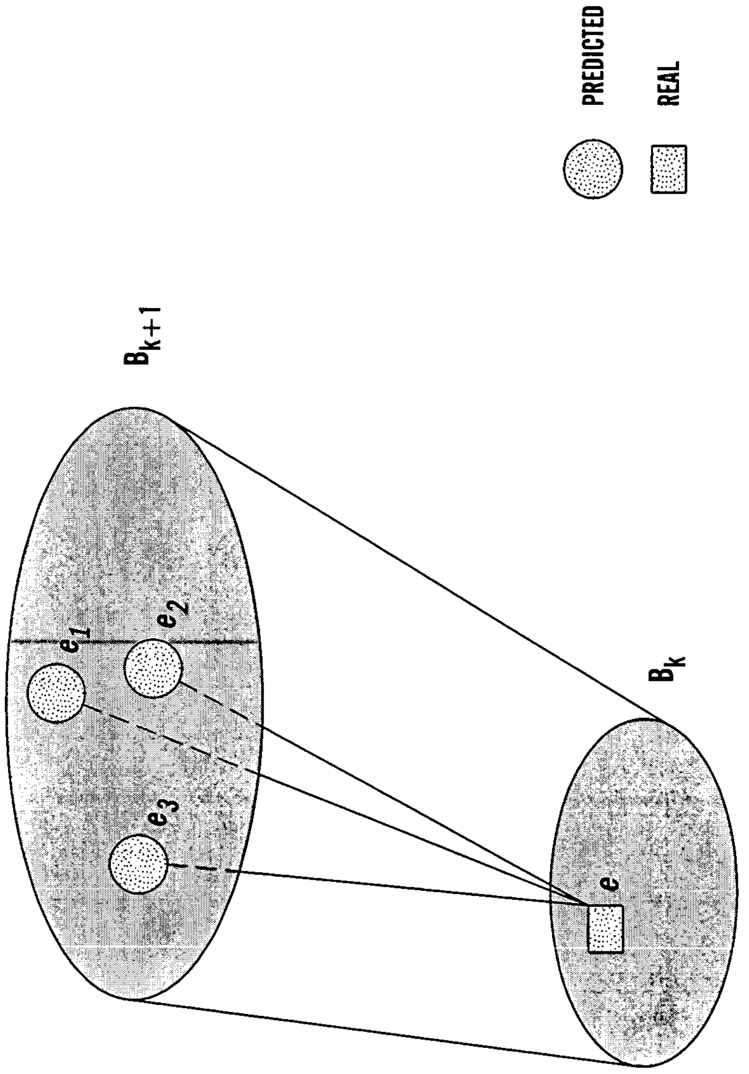

FIG. 1

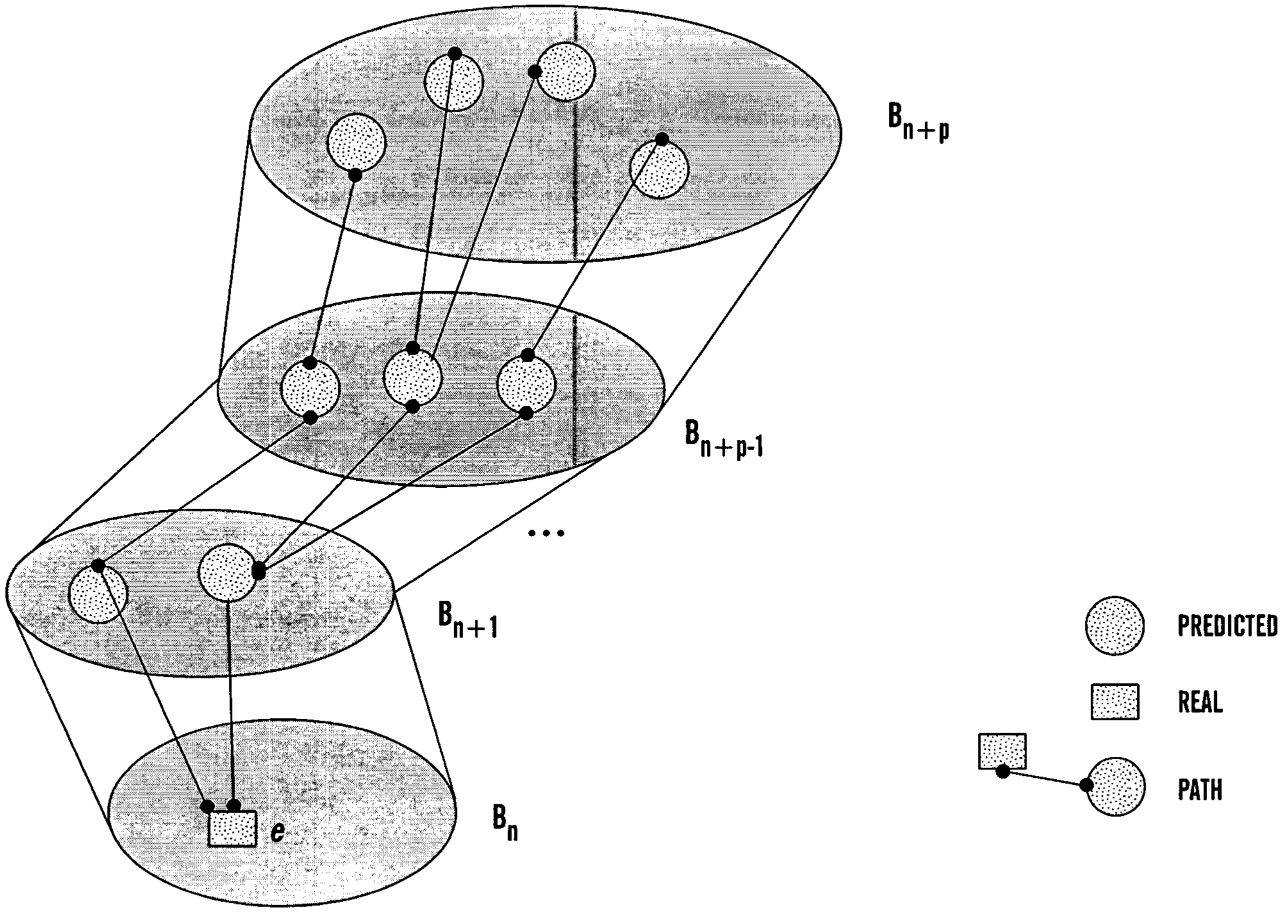

FIG. 2

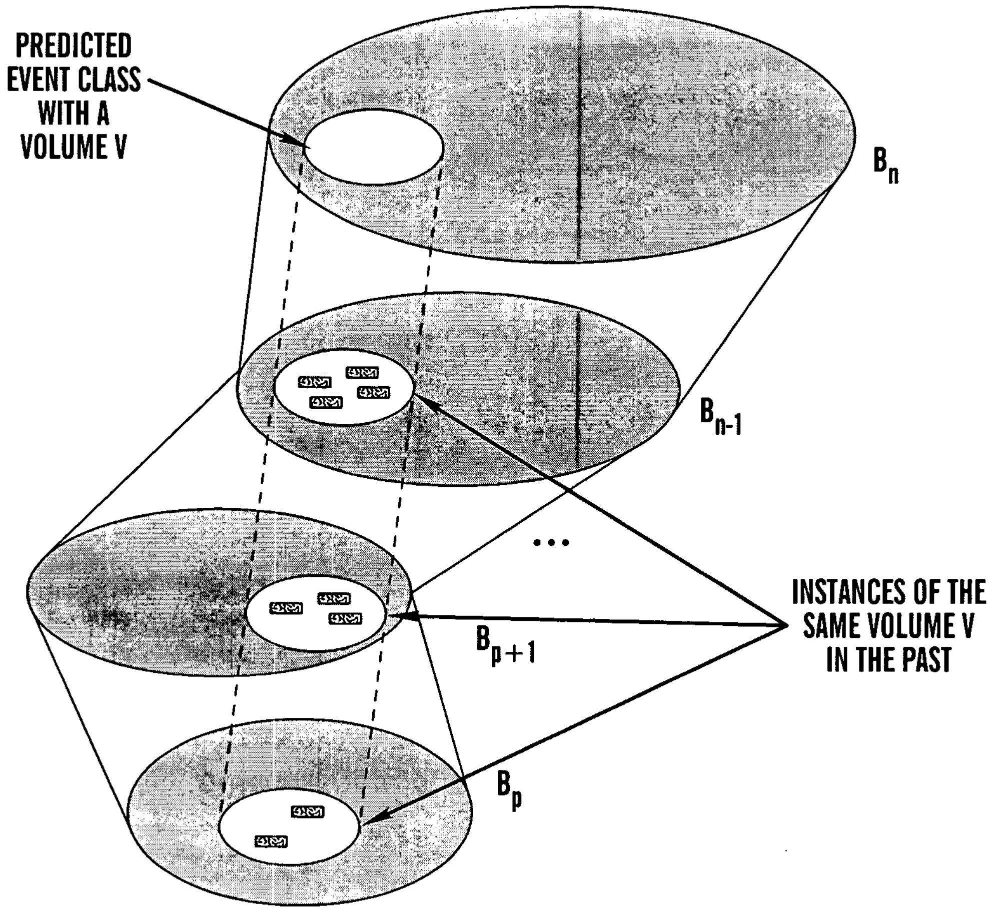
PREDICTED EVENT CLASS WITH A VOLUME V
B_n
B_{n-1}
...
INSTANCES OF THE SAME VOLUME V IN THE PAST
B_{p+1}
B_p

FIG. 3

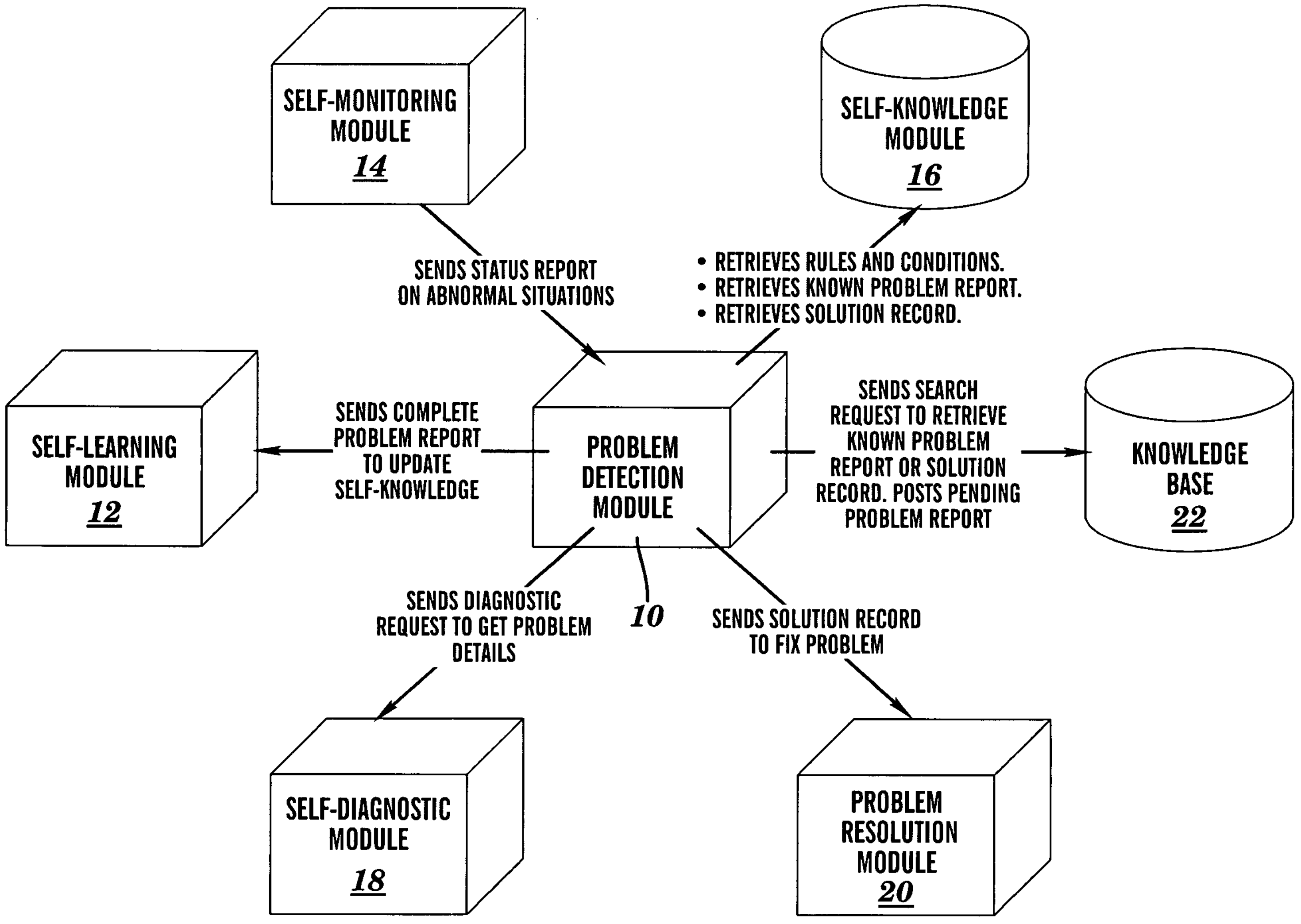
SELF-MONITORING MODULE 14
SELF-KNOWLEDGE MODULE 16
SENDS STATUS REPORT ON ABNORMAL SITUATIONS
• RETRIEVES RULES AND CONDITIONS.
• RETRIEVES KNOWN PROBLEM REPORT.
• RETRIEVES SOLUTION RECORD.
SELF-LEARNING MODULE 12
SENDS COMPLETE PROBLEM REPORT TO UPDATE SELF-KNOWLEDGE
PROBLEM DETECTION MODULE
SENDS SEARCH REQUEST TO RETRIEVE KNOWN PROBLEM REPORT OR SOLUTION RECORD. POSTS PENDING PROBLEM REPORT
KNOWLEDGE BASE 22
SENDS DIAGNOSTIC REQUEST TO GET PROBLEM DETAILS
10
SENDS SOLUTION RECORD TO FIX PROBLEM
SELF-DIAGNOSTIC MODULE 18
PROBLEM RESOLUTION MODULE 20

FIG. 4

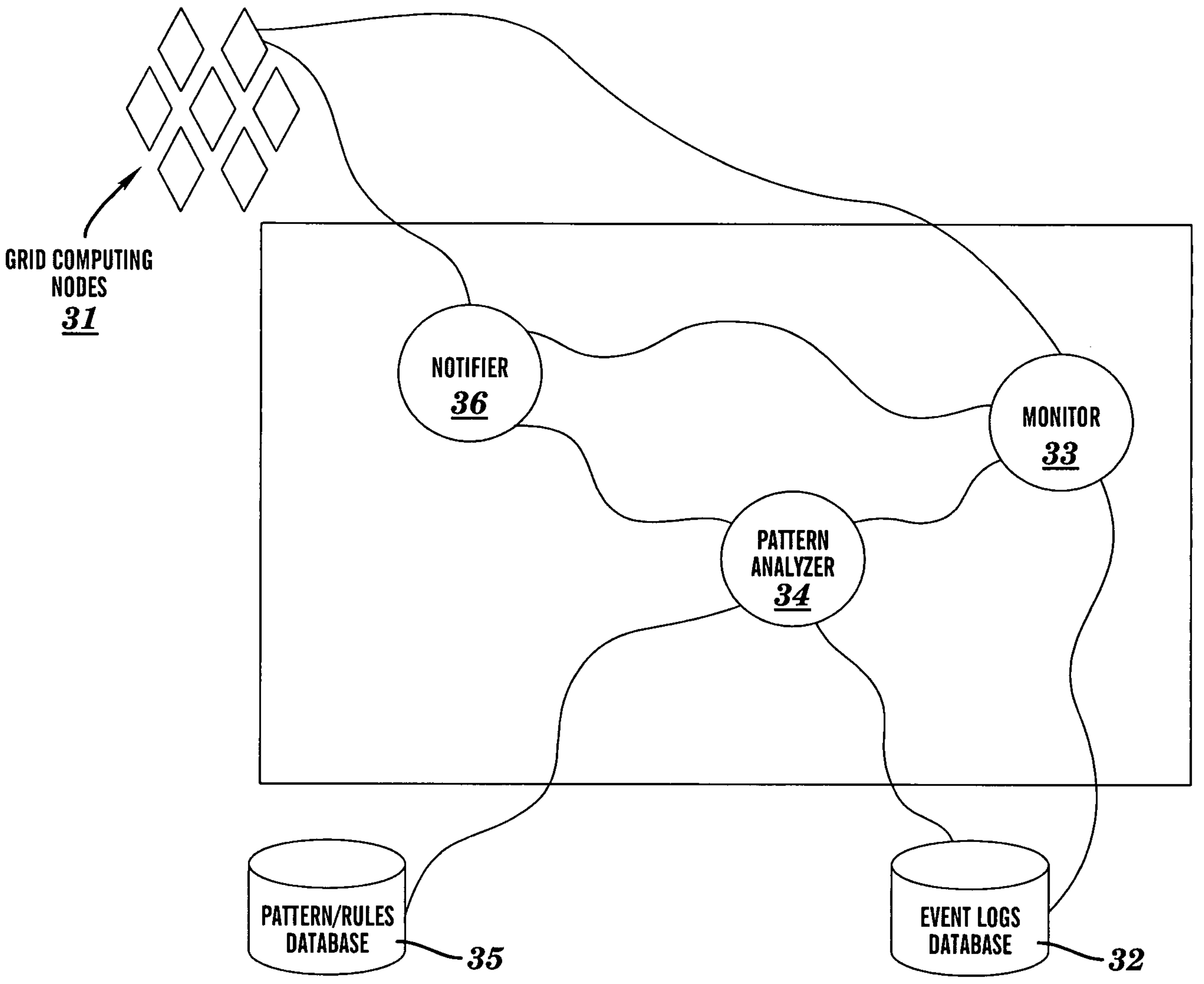
GRID COMPUTING NODES 31
NOTIFIER 36
MONITOR 33
PATTERN ANALYZER 34
PATTERN/RULES DATABASE
35
EVENT LOGS DATABASE
32

FIG. 5

Table of Hardware and Software.

System Components
CPU
BUS
MEMORY
SOFTWARE A
SOFTWARE B

FIG. 6

Table of Operations and Error Types for System Components.

System Component	Operations	Errors
CPU	CPU-Op1	CPU-Error1
	CPU-Op2	CPU-Error2
BUS	BUS-Op1	BUS-Error1
	BUS-Op2	BUS-Error2
MEMORY	MEM-Op1	MEM-Error1
	MEM-Op2	MEM-Error2
SOFTWARE A	SWA-Op1	SWA-Error1
	SWA-Op2	SWA-Error2
SOFTWARE B	SWB-Op1	SWB-Error1
	SWB-Op2	SWB-Error2

FIG. 7

Vector Element Indexes For System Events Represented as Vectors.

Element Index	Operations	Element Index	Errors
1	CPU-Op1	11	CPU-Error1
2	CPU-Op2	12	CPU-Error2
3	BUS-Op1	13	BUS-Error1
4	BUS-Op2	14	BUS-Error2
5	MEM-Op1	15	MEM-Error1
6	MEM-Op2	16	MEM-Error2
7	SWA-Op1	17	SWA-Error1
8	SWA-Op2	18	SWA-Error2
9	SWB-Op1	19	SWB-Error1
10	SWB-Op2	20	SWB-Error2

FIG. 8

Events.

Month	Events	Number of occurrences
1	$E_1 = (0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0)$	200
	$E_2 = (0,0,0,0,0,0,0,1,0,1,0,0,0,0,0,0,0,0,0)$	40
	$E_3 = (1,0,0,0,1,0,1,1,0,1,0,1,1,0,1,0,0,1,0,0)$	10
	$E_4 = (1,0,0,0,1,0,0,0,0,1,0,1,1,0,1,0,0,1,0,0)$	7
2	$E_5 = (1,0,0,1,1,0,0,0,0,1,0,1,1,0,1,0,0,0,0,0)$	150
	$E_{10} = (1,0,0,1,1,0,0,0,0,1,0,1,0,0,1,0,0,0,0,0)$	30
	$E_{12} = (1,0,0,1,1,0,0,0,0,1,0,0,0,0,1,0,0,0,0,0)$	10
	$E_{15} = (1,0,0,0,1,0,0,0,0,1,0,0,0,0,1,0,0,0,0,0)$	7
3	$E_{16} = (1,0,1,0,0,0,0,0,0,1,0,0,0,0,1,0,0,0,0,0)$	29
	$E_6 = (1,0,1,0,0,0,0,0,0,1,0,1,1,0,1,0,0,0,0,0)$	149
	$E_{11} = (1,1,0,1,0,1,0,1,0,1,0,0,1,0,1,0,0,0,0,0)$	7
4	$E_8 = (1,0,0,0,0,0,0,0,0,1,0,0,0,0,1,1,0,1,0,0)$	149
	$E_7 = (1,0,0,0,0,0,0,0,0,1,0,0,0,0,1,0,1,1,0,0)$	29
	$E_9 = (1,0,0,0,0,0,0,0,0,1,0,0,0,0,1,0,0,0,1,0)$	6
	$E_{13} = (1,0,0,0,0,0,0,0,0,1,0,0,0,0,1,0,0,0,1,1)$	7
5	$E_{18} = (1,0,0,1,0,0,0,0,0,1,0,0,0,0,1,0,0,0,0,0)$	140
	$E_{17} = (1,0,0,1,0,0,0,0,0,1,0,0,0,0,1,0,0,0,0,1)$	25
	$E_{14} = (0,0,1,0,1,0,0,1,0,1,0,1,0,0,1,0,0,0,0,0)$	6
6	$E_{19} = (0,0,0,0,0,0,0,0,1,1,0,0,0,0,1,0,0,0,0,0)$	139
	$E_{20} = (0,0,1,0,0,0,0,0,1,1,0,0,0,0,1,0,0,0,0,0)$	24
	$E_{15} = (1,0,0,0,0,0,0,0,0,1,0,0,0,0,1,0,1,0,0,0)$	6
	$E_{16} = (1,0,0,0,0,0,0,0,0,1,0,0,0,0,1,0,0,0,0,0)$	5

FIG. 9

Association Rules.

Association Rule	Probability	Association Rule	Probability
$E_1 \Rightarrow E_5$	75%	$E_3 \Rightarrow E_{12}$	100%
$E_5 \Rightarrow E_6$	99%	$E_{12} \Rightarrow E_{11}$	70%
$E_6 \Rightarrow E_8$	100%	$E_{11} \Rightarrow E_9$	85%
$E_8 \Rightarrow E_{18}$	93%	$E_9 \Rightarrow E_{14}$	100%
$E_{18} \Rightarrow E_{19}$	99%	$E_{14} \Rightarrow E_{15}$	100%
$E_2 \Rightarrow E_{10}$	75%	$E_4 \Rightarrow E_{15}$	100%
$E_{10} \Rightarrow E_{16}$	96%	$E_{15} \Rightarrow E_{11}$	100%
$E_{16} \Rightarrow E_7$	100%	$E_{11} \Rightarrow E_{13}$	100%
$E_7 \Rightarrow E_{17}$	86%	$E_{13} \Rightarrow E_{14}$	85%
$E_{17} \Rightarrow E_{20}$	96%	$E_{14} \Rightarrow E_{16}$	83%

FIG. 10

Association Rule	Probability
$E_1 \Rightarrow E_5$	75%
$E_5 \Rightarrow E_6$	99%

FIG. 11

Event Sequence	Probability
$E_1 \rightarrow E_5 \rightarrow E_6$	75%*99% = 74%

FIG. 12

Event Sequences.

Event Sequence	Probability
$E_1 \rightarrow E_5 \rightarrow E_6 \rightarrow E_8 \rightarrow E_{18} \rightarrow E_{19}$	69%
$E_2 \rightarrow E_{10} \rightarrow E_{16} \rightarrow E_7 \rightarrow E_{17} \rightarrow E_{20}$	60%
$E_3 \rightarrow E_{12} \rightarrow E_{11} \rightarrow E_9 \rightarrow E_{14} \rightarrow E_{15}$	70%
$E_4 \rightarrow E_{15} \rightarrow E_{11} \rightarrow E_{13} \rightarrow E_{14} \rightarrow E_{16}$	71%

FIG. 13

Clusters.

Month	Clusters	Events
1	C_1	$E_1 = (0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0)$
		$E_2 = (0,0,0,0,0,0,0,1,0,1,0,0,0,0,0,0,0,0,0)$
	C_2	$E_3 = (1,0,0,0,1,0,1,1,0,1,0,1,1,0,1,0,0,1,0,0)$
		$E_4 = (1,0,0,0,1,0,0,0,0,1,0,1,1,0,1,0,0,1,0,0)$
2	C_3	$E_5 = (1,0,0,1,1,0,0,0,0,1,0,1,1,0,1,0,0,0,0,0)$
		$E_{10} = (1,0,0,1,1,0,0,0,0,1,0,1,0,0,1,0,0,0,0,0)$
	C_4	$E_{12} = (1,0,0,1,1,0,0,0,0,1,0,0,0,0,1,0,0,0,0,0)$
		$E_{15} = (1,0,0,0,1,0,0,0,0,1,0,0,0,0,1,0,0,0,0,0)$
3	C_5	$E_{16} = (1,0,1,0,0,0,0,0,0,1,0,0,0,0,1,0,0,0,0,0)$
		$E_6 = (1,0,1,0,0,0,0,0,0,1,0,1,1,0,1,0,0,0,0,0)$
	C_6	$E_{11} = (1,1,0,1,0,1,0,1,0,1,0,0,1,0,1,0,0,0,0,0)$
4	C_7	$E_8 = (1,0,0,0,0,0,0,0,0,1,0,0,0,0,1,1,0,1,0,0)$
		$E_7 = (1,0,0,0,0,0,0,0,0,1,0,0,0,0,1,0,1,1,0,0)$
	C_8	$E_9 = (1,0,0,0,0,0,0,0,0,1,0,0,0,0,1,0,0,0,1,0)$
		$E_{13} = (1,0,0,0,0,0,0,0,0,1,0,0,0,0,1,0,0,0,1,1)$
5	C_9	$E_{18} = (1,0,0,1,0,0,0,0,0,1,0,0,0,0,1,0,0,0,0,0)$
		$E_{17} = (1,0,0,1,0,0,0,0,0,1,0,0,0,0,1,0,0,0,0,1)$
	C_{10}	$E_{14} = (0,0,1,0,1,0,0,1,0,1,0,1,0,0,1,0,0,0,0,0)$
6	C_{11}	$E_{19} = (0,0,0,0,0,0,0,0,1,1,0,0,0,0,1,0,0,0,0,0)$
		$E_{20} = (0,0,1,0,0,0,0,0,1,1,0,0,0,0,1,0,0,0,0,0)$
	C_{12}	$E_{15} = (1,0,0,0,0,0,0,0,0,1,0,0,0,0,1,0,1,0,0,0)$
		$E_{16} = (1,0,0,0,0,0,0,0,0,1,0,0,0,0,1,0,0,0,0,0)$

FIG. 14

Sequences of Clusters.

Sequence of Clusters	Probability
$C_1 \rightarrow C_3 \rightarrow C_5 \rightarrow C_7 \rightarrow C_9 \rightarrow C_{11}$	41%
$C_2 \rightarrow C_4 \rightarrow C_6 \rightarrow C_8 \rightarrow C_{10} \rightarrow C_{12}$	50%

FIG. 15

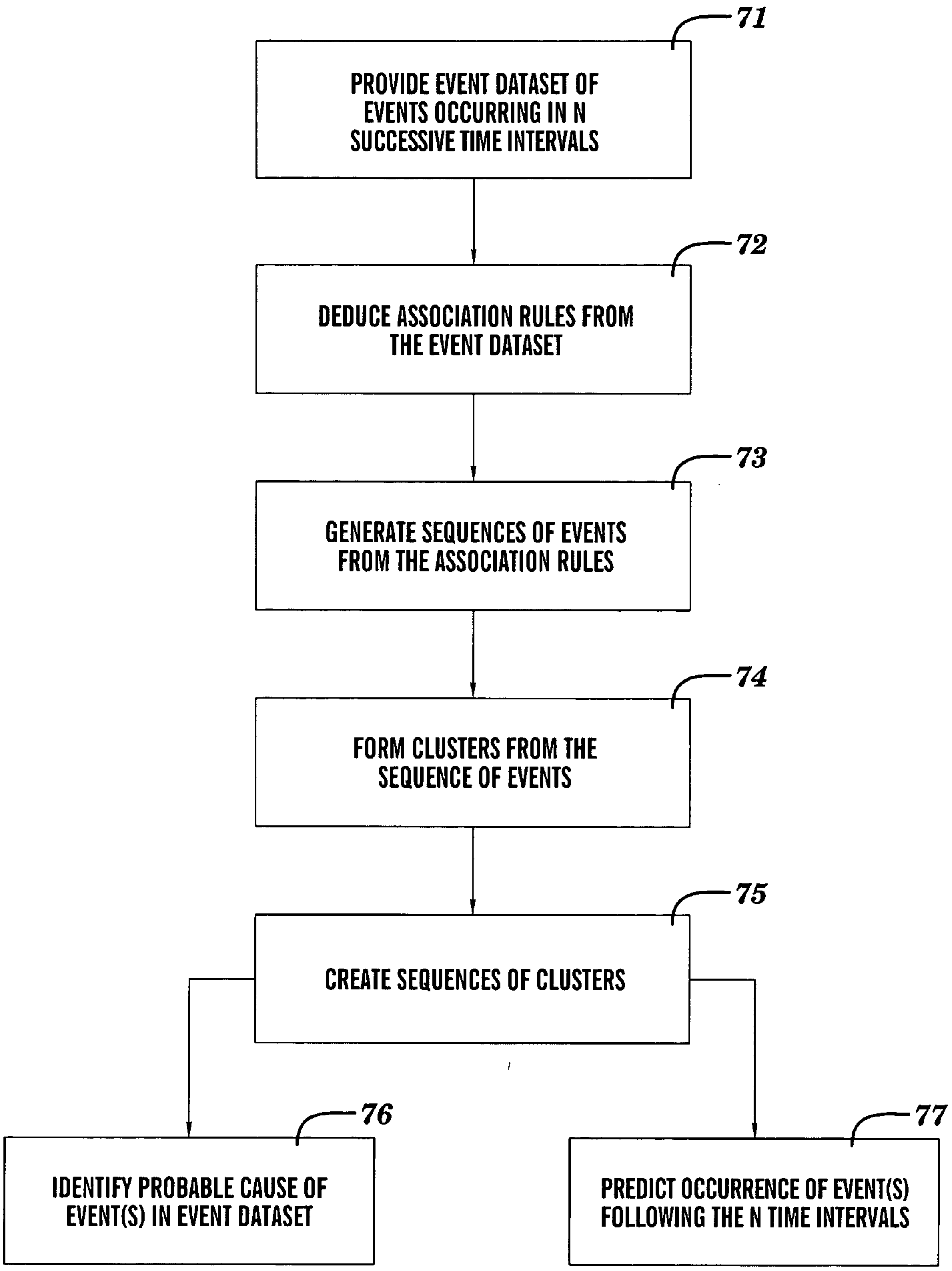
71
PROVIDE EVENT DATASET OF EVENTS OCCURRING IN N SUCCESSIVE TIME INTERVALS
72
DEDUCE ASSOCIATION RULES FROM THE EVENT DATASET
73
GENERATE SEQUENCES OF EVENTS FROM THE ASSOCIATION RULES
74
FORM CLUSTERS FROM THE SEQUENCE OF EVENTS
75
CREATE SEQUENCES OF CLUSTERS
76
IDENTIFY PROBABLE CAUSE OF EVENT(S) IN EVENT DATASET
77
PREDICT OCCURRENCE OF EVENT(S) FOLLOWING THE N TIME INTERVALS

FIG. 16

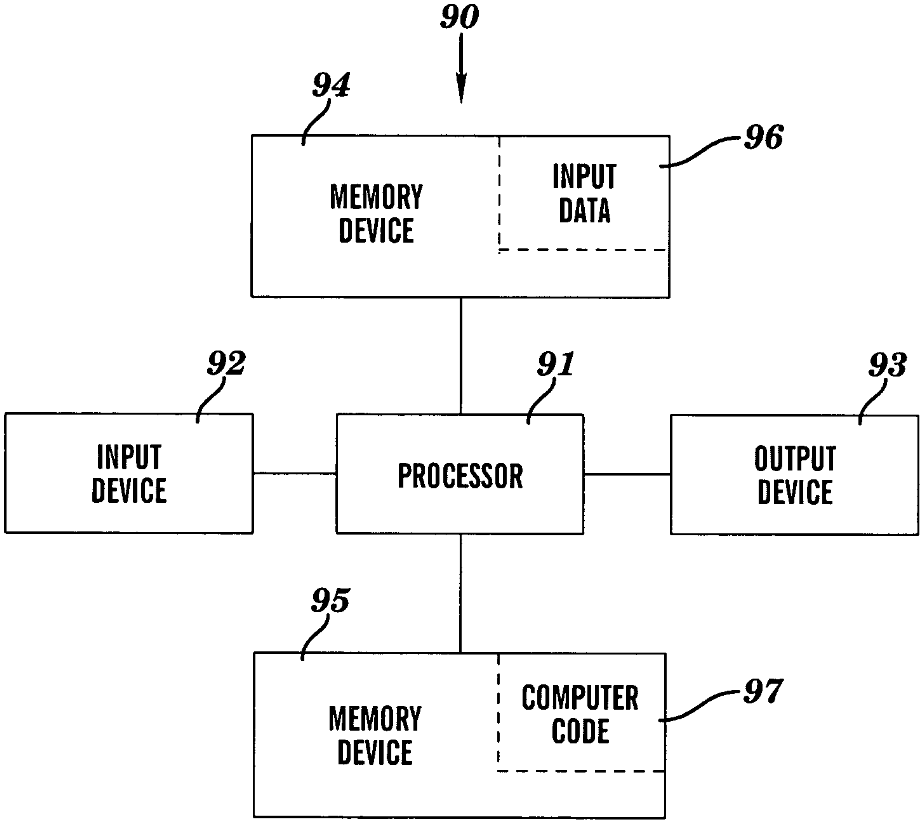
90
94
MEMORY DEVICE
INPUT DATA
96
92
INPUT DEVICE
91
PROCESSOR
93
OUTPUT DEVICE
95
MEMORY DEVICE
COMPUTER CODE
97

FIG. 17